

## Description

### Combustor of a Gas Turbine Engine

#### Technical Field

- [01] This invention relates generally to a gas turbine engine and more specifically to cooling of a liner of a combustor of a gas turbine engine.

#### Background

- [02] Current gas turbine engines continue to improve emissions and engine efficiencies. Notwithstanding these improvements, further increases in engine efficiencies will require more effective use of a mass of compressed air exiting a compressor. Gas turbine engines normally use the mass of compressed air for: 1) combustion air, 2) dilution air, 3) combustor cooling air, and 4) turbine component cooling air. Each use of the mass of compressed air may vary according to a load on the gas turbine engine. Generally each of these uses requires more of the mass of compressed air as the load increases.
- [03] In particular, combustion air and combustor cooling air have increased in importance with increasing regulations of NO<sub>x</sub> (an uncertain mixture of oxides of nitrogen). The efficiencies of the gas turbine engine usually improve with increased temperatures entering a turbine. Unlike the efficiency of the gas turbine engine, decreasing NO<sub>x</sub> production in gas turbine engines typically involves reducing a flame temperature. Lean premixed combustion attempts to decrease NO<sub>x</sub> production while maintaining gas turbine engine efficiencies. A lean premixed combustor premixes a mass of combustion air and a quantity of fuel upstream of a primary combustion zone. Increasing the mass of combustion air reduces the flame temperature by slowing a chemical reaction between the fuel and the combustion air. By reducing the flame temperature, NO<sub>x</sub> production

also decreases. A lean premixed fuel injector assembly is shown in U.S. Patent No. 5,467,926 issued to Idleman et al. on 21 November 1995.

[04] Even with the lower flame temperatures, a liner wall of the combustor must be maintained at an operating temperature meeting a durability requirement. A number of cooling schemes may be used to cool the combustor liner including film cooling, convection cooling, effusion cooling, and impingement cooling. However, one problem shared by many different cooling schemes is an inability to obtain the maximum cooling potential from the available mass of cooling air while still maintaining low emissions. For example, one potential problem with film cooling, a very effective cooling method, is the formation of carbon monoxide at the periphery of the combustor.

[05] The combustor of the present invention solves one or more of the problems set forth above.

#### Summary of the Invention

[06] An embodiment of a combustor has a combustion zone and a first liner bounding the combustion zone. The first liner has a first end portion and a second end portion spaced a defined distance from the first end portion. The combustor has a first convector spaced apart from the first liner. The convector has a first end portion and a second end portion spaced a defined distance from the first end portion. The combustor has a plurality of passages positioned between the first liner and the first combustor liner. At least one of the plurality of passages has a length that is greater than at least one of the defined distance of the first liner and the defined distance of the first convector.

[07] An embodiment of a gas turbine engine has a compressor, a combustor, and a turbine. The combustor has a combustion zone and a first liner bounding the combustion zone. The first liner has a first end portion and a second end portion spaced a defined distance from the first end portion. The combustor has a first convector spaced apart from the first liner. The convector has a first end portion and a second end portion spaced a defined distance from

the first end portion. The combustor has a plurality of passages positioned between the first liner and the first combustor liner. At least one of the plurality of passages has a length that is greater than at least one of the defined distance of the first liner and the defined distance of the first convector.

[08] In a further embodiment of the present invention, a method of cooling a liner of a combustor of a gas turbine engine includes directing a fluid between a first end portion of a first liner and a first end portion of a first convector of a combustor. At least one of the first liner and the first convector has a central axis. The method further includes causing the fluid to move in a direction nonparallel to the central axis.

[09] In another embodiment of the present invention, a combustor has a combustion zone and a first liner bounding the combustion zone. The combustor has a first convector spaced apart from the first liner. At least one of the first liner and the first convector has a central axis. The combustor has a fluid disposed between the first liner and the first convector. The combustor has means for causing the fluid to move in a direction nonparallel to the central axis.

#### Brief Description of the Drawings

[10] Fig. 1 is a cross-sectional view of a portion of a gas turbine engine;

[11] Fig. 2 is an enlarged cross-sectional view of a combustor of the gas turbine engine of Fig. 1;

[12] Fig. 3 is a perspective view of one embodiment of the combustor of Fig. 2; and

[13] Fig. 4 is a perspective view of an alternative embodiment of the combustor of Fig. 2.

#### Detailed Description

[14] Referring to Fig. 1, an embodiment of a gas turbine engine 10 is shown having a compressor 12, a combustor 14, and a turbine 16. The combustor

14 is in fluid communication with the compressor 12, and the turbine 16 is in fluid communication with the combustor 14. The turbine 16 is connected to the compressor 12 via a force-transmitting device 17, such as a shaft or gear system. The combustor 14 defines a combustion zone 18 of the gas turbine engine 10. In the embodiment of Fig. 1, the combustor 14 of the gas turbine engine 10 is an annular combustor and has a central axis 20. However, in other embodiments, the combustor 14 may be tubular with a single can, tubular with multiple cans, tuboannular, or any other configuration known in the art. In the embodiment of Fig. 1, the combustor 14 is generally in the shape of a cylinder joined to a conical frustum. However, the combustor 14 may approximate any other shape or combination of shapes, such as a cylinder, an elliptic cylinder, a barrel, a funnel or a conical frustum.

[15] Referring to Fig. 2, a portion of the combustor 14 is shown. The combustor 14 has a combustion zone 18 and a first liner 22 bounding the combustion zone 18. As used herein, the term "bounding" shall mean "providing a limit to." The first liner 22 has a first end portion 24 and a second end portion 26 spaced a defined distance 28 from the first end portion 24. In the embodiment of Fig. 1, the first liner 22 has a central axis 29 that is generally the same as the central axis 20 of the combustor 14. However, in other embodiments, such as a tubular combustor with multiple cans, the central axis 29 of the first liner 22 may not be generally the same as the central axis 20 of the combustor 14.

[16] Referring to Fig. 2, the combustor 14 also has a first convector 30 spaced apart from the first liner 22. The first convector 30 has a first end portion 32 and a second end portion 34 spaced a defined distance 36 from the first end portion 32. The first liner 22 is disposed between the combustion zone 18 and the first convector 30. A defined volume 38 is disposed between the first liner 22 and the first convector 30. The defined volume 38 has a first end portion 40 and a second end portion 42 spaced apart from the first end portion 40. In the embodiment of Fig. 1, the first convector 30 has a central axis 44 that is generally

the same as the central axis 20 of the combustor 14 and the central axis 29 of the first liner 22. However, in other embodiments, such as a tubular combustor with multiple cans, the central axis 44 of the first convector 30 may not be generally the same as the central axis 20 of the combustor 14. Also, in other embodiments the central axis 44 of the first convector 30 may not be generally the same as the central axis 29 of the first liner 22.

[17] In the embodiment of Fig. 2, the first end portion 24 of the first liner 22 does not contact the first end portion 32 of the first convector 30, such that the first end portion 40 of the defined volume 38 is open. A fluid may pass into the defined volume 38 between the first end portion 24 of the first liner 22 and the first end portion 32 of the first convector 30. In Fig. 2, the second end portion 42 of the defined volume 38 is closed. In other embodiments either or both of the first end portion 40 and the second end portion 42 of the defined volume 38 may be open or closed.

[18] Referring to Fig. 3, the combustor 14 has at least one means 45 for causing a fluid positioned between the first liner 22 and the first convector 30 to move in a direction nonparallel to at least one of the central axis 29 of the first liner 22 and the central axis 44 of the first convector 30. In the embodiment of Fig. 3, the at least one means 45 is a plurality of passages 46 positioned between the first liner 22 and the first convector 30. In the embodiment of Fig. 3, the plurality of passages 46 are formed by a first surface 48 of the first liner 22, a first surface 50 of the first convector 30, and at least one wall 52 connected to the first liner 22 and the first convector 30. However, in other embodiments the at least one wall 52 may be connected to only one of the first liner 22 and the first convector 30. In the embodiment of Fig. 3, the at least one wall 52 is a continuous wall, but in other embodiments the at least one wall 52 may be formed by a plurality of wall portions. The plurality of wall portions may be spaced apart. One ordinary skill in the art will recognize that other structures

may perform substantially the same function as the at least one wall 52 and that any of such structures may be substituted for the at least one wall 52.

[19] Referring to Fig. 2, each of the plurality of passages 46 has a first end portion 54 proximate one or both of the first end portion 24 of the first liner 22 and the first end portion 32 of the first convector 30. Each of the plurality of passages 46 has a second end portion 56 proximate one or both of the second end portion 26 of the first liner 22 and the second end portion 34 of the first convector 30. Referring to Fig. 3, each of the plurality of passages 46 has a length defined as the length of a line 58 that is positioned halfway between the at least one wall 52 defining the passage 46 and that extends from the first end portion 54 of the passage 46 to the second end portion 56 of the passage 46. The length of at least one of the plurality of passages 46 is greater than either one or both of the defined distance 28 of the first liner 22 and the defined distance 36 of the first convector 30.

[20] In the embodiment of Fig. 2 and Fig. 3, the plurality of passages 46 are spiral passages, i.e. the at least one wall 52 of the passages 46 rotates about at least one of the central axis 20 of the combustor 14, the central axis 29 of the first liner 22, and the central axis 44 of the first convector 30. In the embodiment of Fig. 4, the passages 46 are serpentine passages. Other passage configurations are possible so long as the length of at least one of the plurality of passages 46 is longer than either the defined distance 28 of the first liner 22 or the defined distance 36 of the first convector 30. In Fig. 3, the combustor 14 has three passages 46. However, one of ordinary skill in the art will recognize that the combustor 14 may have other numbers of passages 46.

[21] Referring to Fig. 2, at least one of the plurality of passages 46 has a first surface 60. In the embodiment of Fig 2, the first surface 60 is formed by the first surface 48 of the first liner 22. At least one of the plurality of passages 46 may have at least one cooling device 62 positioned therein. In the embodiment of Fig. 2, the at least one cooling device 62 is connected to the first

surface 60 of the passage 46. In the embodiment of Fig. 2, the at least one cooling device 62 is a dimple 64, such as the dimple described in U.S. Patent 6,098,397 issued to Glezer et al. on 8 August 2000. However, one of ordinary skill in the art will recognize that other cooling devices 62 may be used, such as trip strips, fins, or pins. Also, in other embodiments at least one cooling device 62 may be connected to a second surface 66 of at least one of the plurality of passages 46. Such second surface 66 may be formed by the first surface 50 of the first convector 30.

[22] In the embodiment of Figs. 1 and 2, the combustor 14 has a second liner 68 bounding the combustion zone 18. The second liner 68 has a first end portion 70 and a second end portion 72 spaced a defined distance 74 from the first end portion 70 of the second liner 68. In the embodiment of Fig. 1, the second liner 68 has a central axis 76 that is generally the same as the central axis 20 of the combustor 14. However, in other embodiments, such as a tubular combustor with multiple cans, the central axis 76 of the second liner 68 may not be generally the same as the central axis 20 of the combustor 14.

[23] In the embodiments of Fig. 1 and 2, the combustor 14 also has a second convector 78 spaced apart from the second liner 68. The second convector 78 has a first end portion 80 and a second end portion 82 spaced a defined distance 84 from the first end portion 80. The second liner 68 is disposed between the combustion zone 18 and the second convector 78. A second defined volume 86 is disposed between the second liner 68 and the second convector 78. The second defined volume 86 has a first end portion 88 and a second end portion 90 spaced apart from the first end portion 88. In the embodiment of Fig. 1, the second convector 78 has a central axis 92 that is generally the same as the central axis 20 of the combustor 14 and the central axis 76 of the second liner 68. However, in other embodiments, such as a tubular combustor with multiple cans, the central axis 92 of the second convector 78 may not be generally the same as the central axis 20 of the combustor 14. Also, in other embodiments the central

axis 92 of the second convector 78 may not be generally the same as the central axis 76 of the second liner 68.

- [24] In the embodiment of Fig. 2, the combustor 14 has a second plurality of passages 94 positioned between the second liner 68 and the second convector 78. In Fig. 2, the second plurality of passages 94 are formed by at least one wall 96. Other features of the second liner 68, second convector 78, second plurality of passages 94, and the at least one wall 96 forming the second plurality of passages 94 are similar to those features set forth above of the first liner 22, first convector 30, plurality of passages 46 and at least one wall 52 forming the plurality of passages 46.

#### Industrial Applicability

- [25] During operation of the gas turbine engine 10, a fluid, typically air, enters the compressor 12 of the engine 10. The compressor 12 compresses the fluid and delivers the compressed fluid to the combustor 14. A portion of the compressed fluid is delivered to the combustion zone 18 of the combustor 14 where it is combusted with gas. This combustion process creates energy, a portion of which is used to drive the turbine 16 of the gas turbine engine 10. Another portion of the energy created by the combustion process manifests itself as heat. This portion of energy increases the temperature of the first liner 22 of the combustor 14.

- [26] To cool the first liner 22, another portion of the compressed fluid from the compressor 12, hereinafter referred to as "the cooling portion of the compressed fluid," is directed into the first end portion 54 of the plurality of passages 46 of the combustor 14. The motion of the cooling portion of the compressed fluid within the plurality of passages 46 will be described by focusing on one of the plurality of passages 46. The cooling portion of the compressed fluid enters the first end portion 54 of the passage 46. The cooling portion of the compressed fluid contacts the first surface 60 of the passage 46 and, thereby, withdraws heat from the first liner 22 of the combustor 14. In



addition, the cooling portion of the compressed fluid contacts the at least one wall 52 of the passage 46 causing the cooling portion of the compressed fluid to move in a direction nonparallel to at least one of the central axis 20 of the combustor 14, the central axis 29 of the first liner 22, and the central axis 44 of the first convector 30. As used herein, “a direction nonparallel to” one of the central axes 20, 29, and 30 refers to the general direction of the majority of the cooling portion of the compressed fluid, not the particular movement of each individual fluid molecule. In addition, “a direction nonparallel to” one of the central axes 20, 29, and 30 is not intended to describe movement in a direction towards or away from one of the central axes 20, 29, and 30, e.g. the movement of the cooling portion of the compressed fluid typically caused by cooling devices 62, such as trip strips. Rotation of the cooling portion of the compressed fluid about at least one of the central axes 20, 29, and 30 is an example of movement of the cooling portion of the compressed fluid in a direction nonparallel to at least one of the central axes 20, 29, and 30. If the passage 46 is a spiral passage, the cooling portion of the compressed fluid is caused to move in a spiral path. If the passage 46 is a serpentine passage, the cooling portion of the compressed fluid is caused to move in a serpentine path. During its movement through such a serpentine path, the cooling portion of the compressed fluid may travel in a direction parallel to at least one of the central axes 20, 29, and 30, but at other points in the serpentine path the cooling portion of the compressed fluid will be caused to move in a direction nonparallel to at least one of the central axes 20, 29, and 30.

[27]                    Extending the length of the passage 46 ensures utilization of a greater cooling capacity of the cooling portion of the compressed fluid between the first liner 22 and the first convector 30. In combustors 14 wherein the cooling portion of the compressed fluid between the first liner 22 and the first convector 30 simply travels either the defined distance 28 of the first liner 22 or the defined distance 36 of the first convector 30, the cooling portion of the compressed fluid

may still have some cooling capacity remaining when the fluid exits the defined volume 38 between the first liner 22 and the first convector 30. If the passage 46 has one or more cooling devices 62 connected to the first surface 60, the cooling effect of the cooling portion of the compressed fluid is increased. The cooling portion of the compressed fluid contacts the cooling device 62, and the cooling device 62 introduces turbulence into the flow of the cooling portion of the compressed fluid. Therefore, a warmer segment of the cooling portion of the compressed fluid that is near the first liner 22 is moved away from the first liner 22 and a cooler segment of the cooling portion of the compressed fluid that is near the first convector 30 moves towards the first liner 22, where it can increase the cooling of the first liner 22.

[28]                    In the embodiments described herein, compressed fluid enters the plurality of passages 46 via open first end portions 54 of the passages 46. However, other means of entrance into the plurality of passages 46 may be utilized, such as impingement jets or other orifices. In an alternative embodiment not shown, in which the gas turbine engine 10 has a serial cooling system, the cooling portion of the compressed fluid may enter the plurality of passages 46 proximate the second end portion 56 of the passages 46 and exit proximate the first end portion 54 of the passages 46.

[29]                    The operation of the second liner 68, second convector 78, second plurality of passages 94, and at least one wall 96 forming the second plurality of passages 94, in embodiments having such structures, is similar to the operation discussed above of the first liner 22, first convector 30, plurality of passages 46, and at least one wall 52 forming the plurality of passages 46.

[30]                    Other aspects, objects, and advantages of this invention can be obtained from a study of the drawings, the disclosure, and the appended claims.